Uniform flow profiles improve horizontal wells

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HORIZONTAL WELLS ARE often utilized to maximize reservoir contact and improve both hydrocarbon recovery efficiency and total well productivity. However, long horizontal wells create non-uniform flux profiles due to variations in formation characteristics and frictional effects in the wellbore that can limit the useful length of the horizontal section and shorten productive well life.

To address this challenge, **Baker Oil Tools** worked with operating companies to develop a completion system that segments the lateral and equalizes longitudinal inflow along the entire production profile of a horizontal wellbore. This system provides operators a completion solution that maximizes reserve recovery by minimizing water- or gas-coning risks and preventing "hot spotting"-induced erosion of sand control screens.

As a result, operators can optimize reservoir production from fewer wells and significantly reduce field development costs. The completion system includes Baker's EQUALIZER uniform inflow control technology and MPas open-hole annular isolation packer.

This completion solution has been successfully deployed in long horizontal and highly deviated wells with lateral lengths ranging from 1,100 ft to 12,000 ft in both naturally fractured carbonate and sandstone formations.

INFLOW CONTROL NEEDS

Frictional effects associated with producing from the entire lateral in long horizontal wells can be significant relative to the typically low drawdown pressures required to achieve target production rates.

Neglecting friction effects without balancing inflow into the wellbore can result in premature water or gas breakthrough, lower productivity and reduced recovery. In permeable reservoirs, the point of breakthrough varies with permeability. In homogeneous reservoirs, breakthrough commonly occurs at the heel of the lateral section (see Figure 1).

The Equalizer uniform inflow control system consists of a proprietary, low-velocity flow regulator, or inflow control device (ICD), typically integrated with

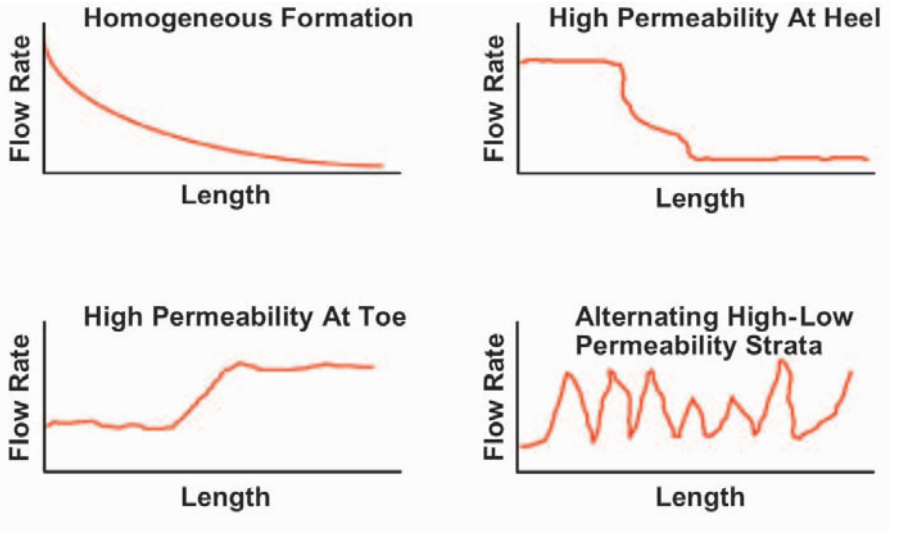

Figure 1 (above): Flux profiles in horizontal wells. **Figure 2a** (below left): The Equalizer inflow control device integrated with a debris filter for carbonate formation applications. **Figure 2b** (below right): Cutaway view of equalizer ICD integrated with a premium sand screen and production flow paths.

Baker's Excluder2000 standalone premium sand screen or a wire-wrap debris filter. (see Figures 2a and 2b).

The ICD incorporates up to three helical flow channels that can be modified for a variety of downhole flow conditions. The helical channels spin the flow before it enters the wellbore, imposing pressure distribution along the entire lateral length and controlling production rate as a function of both the average drawdown pressure and the average productivity of the well.

In reservoirs that require sand control at some point during their productive life, the ICD reduces annular fluid flow velocity and optimizes the inflow velocity into each screen joint. Distributing total production rate evenly among the screen joints in the horizontal section lowers the fluid velocity into each screen sufficiently that erosion and plugging do not occur. If the filtration media in the sand screen is properly designed for solids control, sand management can be achieved without gravel packing.

The number, length and cross-sectional area of the helical flow channels are based on reservoir and production requirements, with their configuration determined by numerical modeling and reservoir simulation. Highly productive zones cannot "overproduce" because they have less reservoir segment drawdown. Similarly, lower pressure in the reservoir-to-ICD region pulls harder on less productive zones to make them produce more. If the well path is close to either water or gas, the uniform flow profile prevents undesired coning effects that lead to premature water and/or gas breakthrough (see Figure 3).

MPas annular isolation packers isolate between zones in the open hole without the need for cement and conform to irregularly shaped wellbores. The hydraulically set, mechanical open-hole packers enhance the positive effects of the Equalizer by creating an annular barrier between sections of varying permeability.

Inflow control technology was jointly defined and developed by Baker Oil Tools and **Norsk Hydro** in the mid-1990s to drain oil from the Troll field. Troll was originally developed as a gas field whose thin oil layer was considered uneconomical to produce because it was trapped in

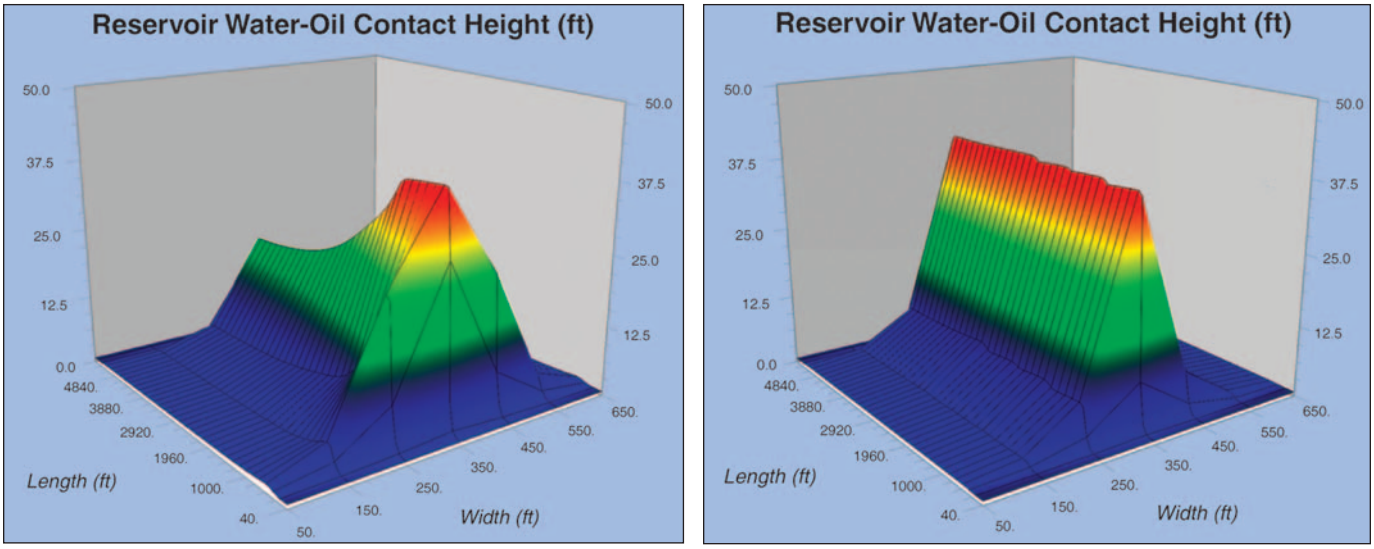

Figure 3: Water-oil contact without EQUALIZER (left) — water breaks through. Water-oil contact with EQUALIZER (right) — notice the uniform flow.

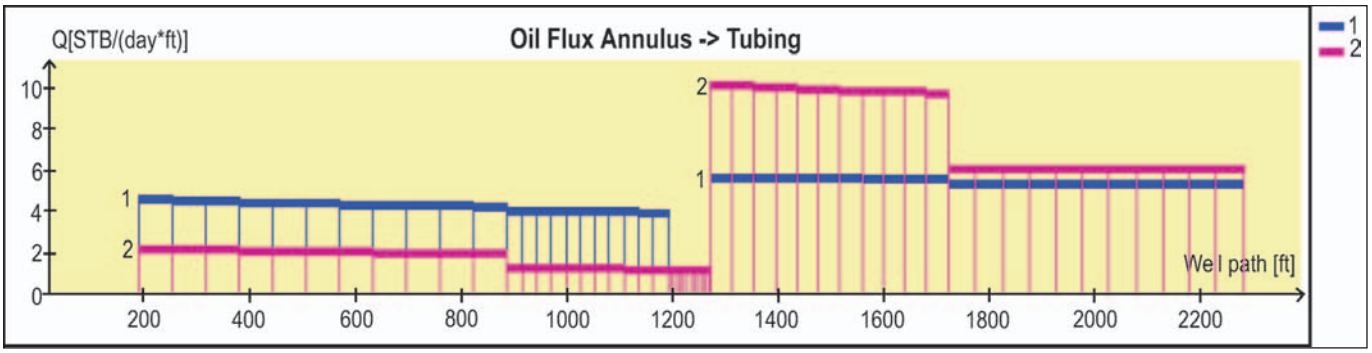

Figure 4: Well Z-253 oil flux annulus to tubing, 1-balanced flow, 2-non uniform inflow.

a high-permeability sandstone formation with both water and gas contacts. Precise, extended-reach drilling maximized reservoir contact, which allowed greater access to reserves. Initially, most of the fluids production came from the first one-third of the horizontal lateral, closest to the heel, with the remaining interval having minimal contribution.

Uniform inflow control technology made it possible to maintain maximum reservoir contact while minimizing the potential for water or gas coning. To date, more than 120 horizontal wells in the North Sea have utilized Equalizer ICDs integrated into sand screens to balance production inflow, prevent water and gas coning, and provide well life sand control without gravel packing.

One of the longest lateral sections to be completed achieved an 11,894-ft (3,619-m) section of open hole in the Troll M-22 well. Based on numerical modeling and reservoir simulation, the open hole was completed with 279 joints of 250-micron premium standalone sand screens.

In the Z-field offshore Saudi Arabia, using uniform inflow control technology added an estimated 2.4 million bbl of incremental production and created a safer operation by eliminating the need for perforation guns on the rig. The Z-field has been producing since 1972, primarily from vertical wells. More recently, a strategic decision was made to switch to horizontal wells. High system backpressure and premature water breakthrough challenges these wells with reduced well productivity and reserve recovery.

In determining the completion efficiency of well Z-253, spinner logs were run to validate the effective producing length (Leff). Quantifying effective producing length helped reduce the error in estimating the mechanical skin damage from production modeling simulation work. The preliminary analysis of the Z-253 log indicated uniform flow contribution across the horizontal section with total rates of ± 8.0 MRBD and ± 10.0 MRBD. The first half of the lateral contributed 43 percent of the total production for the Z-253 well as compared with only 10 percent for the conventional horizontal completion. The estimated Productivity Index (PI) was about 160 stbd/psi for the uniform flow completion (see Figure 4).

Acknowledgements / References

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